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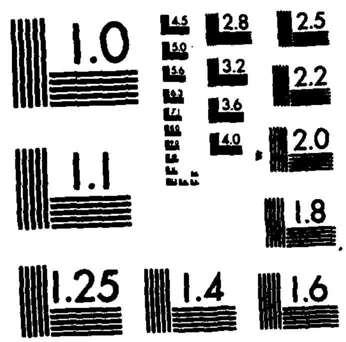

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USAF OEHL REPORT
83-128EH111DGA

FOR HEALTH & ENVIRONMENT

AD-A134814

RATIONALE FOR A THRESHOLD LIMIT VALUE

(TLV)[R] FOR JP-4/JET B WIDE CUT

AVIATION TURBINE FUEL

APRIL 1983

USAF Occupational and Environmental Health Laboratory
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

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Commander

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This report provides rationale for a Threshold Limit Value (TLV)^R of 700 mg/m^3 (200 ppm, 1.5% LEL) and a Short Term Exposure Limit (STEL) of 1050 mg/m^3 (300 ppm, 2.3% LEL) as n-hexane with a "skin" notation for JP-4/Jet B wide cut aviation turbine fuel. This recommendation is based upon a thorough review of the literature and USAF experience with JP-4 fuel exposures.

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HEALTH LABORATORY

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RATIONALE FOR A THRESHOLD LIMIT VALUE (TLV)[R] FOR JP-4/JET B WIDE CUT AVIATION TURBINE FUEL

APRIL 1983

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I. INTRODUCTION

This report provides rationale for a Threshold Limit Value[R] (TLV) of 700 mg/m³ (200 ppm, 1.5% LEL), and a Short-Term Exposure Limit (STEL) of 1050 mg/m³ (300 ppm, 2.3% LEL) as n-hexane with a skin notation for JP-4/Jet B Wide Cut Aviation Turbine Fuel. This recommended value is based upon a thorough review of the literature and USAF experience with JP-4 fuel exposures.

II. RATIONALE FOR STANDARD

JP-4 is the primary fuel used in USAF aircraft. It is a complex blend of up to 300 different hydrocarbon compounds. Minor additives are included to control oxidation, inhibit corrosion and icing and to passivate metal fuel system components. The general characteristics are shown in Table 1. Table 2 contains a more complete description of the additives as specified in military specification MIL-T-5624L, Turbine Fuel, Aviation, Grades JP-4 and JP-5. As seen in Table 2, JP-4 has a very wide distillation range and the lower boiling light ends, C_8 and below, tend to evaporate first leaving the heavier ends from C_9 through C_{16}. As a result, the molecular weight of the vapor to which personnel are exposed is considerably less than the liquid (85 gm/mole versus 125 gm/mole), Table 3. This agrees with the observations of McDermott (1978) who reported the light ends predominate in vapor exposures to gasoline.

TABLE 1

JP-4 General Characteristics Wide Cut, Gasoline Type Fuel

Carbon Range	C_4 - C_{16}
Distillation End Point	270°C (520°F)
LEL, vv%[1]	1.3
UEL, vv%[1]	8.0
Minimum vapor pressure at 100°F, mm Hg	105
Maximum vapor pressure at 100°F, mm Hg	155
Flash Point	-23 to 1°C (-10 to 30°F)

[1] vv% = vapor volume percent

TABLE 2

Chemical and Physical Requirements of JP-4

Requirements	Grade JP-4
Color, Saybolt[1]	
Total acid number, mg KOH/g, max	0.015
Aromatics, vol percent, max	25.0
Olefins, vol percent max	5.0
Mercaptan sulfur, weight percent, max[2]	0.001
Sulfur, total weight percent, max	0.40
Distillation temperature, deg C,	
(D 2887 limits in parentheses)	
Initial boiling point[1]	
10 percent recovered, max temp[1]	
20 percent recovered, max temp	145 (130)
50 percent recovered, max temp	190 (185)
90 percent recovered, max temp	245 (250)
End point, max temp	270 (320)
Residue, vol percent, max (for D 86)	1.5
Loss, vol percent, max (for D 86)	1.5
Explosives percent, max	—
Flash point, deg C (deg F), min	—
Density, kg/m³, min (°API, max) at 15°C	751 (57.0)
Density, kg/m³, max (°API, min) at 15°C	802 (45.0)
Vapor pressure, 37.8°C (100°F), kPa (psi), min	14 (2.0)
Vapor pressure, 37.8°C (100°F), kPa (psi), max	21 (3.0)
Freezing point, deg C (deg F), max	-58 (-72)
Viscosity, at -20°C, max, mm²/s(centistokes)	—
Heating value, aniline-gravity product, min, or net heat of combustion,	5,250
MJ/kg (Btu/lb) min	42.8 (18,400)
Hydrogen content, wt percent, min	13.6
or smoke point, mm, min	20.0

[1]To be reported - not limited.
[2]The mercaptan sulfur determination may be waived at the option of the inspector if the fuel is "doctor sweet" when tested in accordance with the doctor test of ASTM D 484.

JP-4 is primarily aliphatic hydrocarbons (paraffins) with an average concentration of 10-11% aromatics and 1% unsaturated hydrocarbons (Harrison, 1982). As a class, paraffins are generally considered to be central nervous system (CNS) depressants with the exceptions of the first three members of the series, methane, ethane and propane, which are simple asphyxiants and n-hexane which is a peripheral neuropathic agent. The vapors of the paraffins are

TABLE 3

TLV Calculations for JP-4 and Gasoline Headspace Vapor

Compound	Carbon No.	Mol Wt.	TLV (mg/m^3)	JP-4 Area% JP-4	JP-4 Area% ÷ TLV	Gasoline Area% Gas	Gasoline Area% ÷ TLV
Propane	3	44.04	2,000 (2)	1.00	0.000500	2.10	0.001050
Isobutane	4	52.18	1,900 (3)	2.65	0.001395	6.00	0.003158
n-Butane	4	52.18	1,900 (1)	5.60	0.002947	32.50	0.017105
Methyl Butane	5	72.15	1,900 (4)	12.25	0.006447	21.80	0.011474
n-Pentane	5	72.15	1,800 (1)	13.05	0.007250	10.90	0.006056
Dimethyl Butane	6	86.18	1,700 (4)	2.45	0.001441	1.90	0.001118
Methyl Pentane	6	86.18	1,700 (4)	11.30	0.006647	5.50	0.003235
n-Hexane	6	86.18	180 (1)	8.15	0.045278	2.30	0.012778
Methyl Cyclopentane	6	84.16	1,700 (4)	3.45	0.002029	1.00	0.000588
Benzene	6	78.12	30 (1)	1.25	0.041667	0.50	0.016667
Cyclohexane	6	84.16	1,050 (1)	3.10	0.002952	0.30	0.000286
Methyl Hexane	7	100.21	1,600 (3)	2.70	0.001688	0.50	0.000313
Dimethyl Pentane	7	100.21	1,600 (3)	2.70	0.001688	0.00	0.000000
n-Heptane	7	100.21	1,600 (1)	4.30	0.002688	0.40	0.000250
Methyl Cyclohexane	7	98.19	1,600 (1)	2.75	0.001719	0.00	0.000000
Toluene	7	92.15	375 (1)	1.15	0.003067	0.90	0.002400
Methyl Heptane	8	114.23	1,450 (3)	1.50	0.001034	0.00	0.000000
Dimethyl Cyclohexane	8	112.22	1,450 (3)	1.50	0.001034	0.00	0.000000
n-Octane	8	114.23	1,450 (1)	2.00	0.001379	0.10	0.000069
Ethyl Benzene	8	106.17	435 (1)	0.18	0.000414	0.20	0.000460
Xylenes	8	106.17	435 (1)	0.68	0.001563	0.55	0.001264
n-Nonane	9	128.26	1,050 (1)	0.45	0.000429	0.00	0.000000
n-Decane	10	142.29	700 (5)	0.18	0.000257	0.00	0.000000
Others	7	100.21	1,600 (6)	15.66	0.009788	12.55	0.007844
TOTAL				100.00	0.145300	100.00	0.086113

	JP-4	Gasoline
TLV (mg/m^3)	688.23	1161.26
TLV (ppm)	196.03	403.37
Avg MW (gm/mole)	85	70
Avg C#	6	5
Based on hexane and benzene (7)		
TLV (mg/m^3)	696.53	1108.72
TLV (ppm)	198.39	385.12

(1) ACGIH TLV (1982)
(2) Simple asphyxiant
(3) Calculated from the TLV of the normal alkane with the same carbon number
(4) Estimated from the extrapolated C_6 alkane TLV assuming no neurotoxicity
(5) Extrapolated from the n-octane and n-nonane TLVs
(6) Estimate from the distribution of the majority of the minor components which were near C_7 in the chromatograms
(7) Calculated from the benzene and n-hexane concentrations assuming the remaining hydrocarbons are C_7 alkanes

generally considered to be irritating to the mucous membranes, but direct liquid contact with the lungs will cause pneumonitis (Gerarde, 1962a). Aromatics are also generally considered to be CNS depressants. Additionally, benzene exerts a toxic effect on the blood-forming organs in the bone marrow (Gerarde, 1962b). Benzene is also a suspect carcinogen and requires special consideration. In general, the aromatics are also more irritating to the mucous membrane than the aliphatics (Gerarde, 1962b).

The only completed toxicology study involving JP-4 was conducted at the Air Force Aerospace Medical Research Laboratory (AFAMRL) by Kinkead (1974). Beagle dogs, monkeys, mice and rats were exposed to concentrations of 2500 mg/m^3 or 5000 mg/m^3 for 6 hr/day, 5 days/wk for 33 weeks. These levels were selected to produce levels of 12.5 and 25 parts per million (ppm) benzene under the theory that benzene was the primary toxic chemical in the mixture. During the first three weeks of exposure, the dogs and monkeys both showed decreased activity but regained normal levels of activity by the fourth week. Kinkead also reported an increase in red blood cell (RBC) osmotic fragility in female beagle dogs exposed to the 5000 mg/m^3 concentration and two mice developed pulmonary adenomas. One mouse in the group of 19 exposed to 5000 mg/m^3 had lymphosarcomas in the lungs and lymph nodes with metastases to other organs. Based on no observed effect level at 2500 mg/m^3, they recommended this value as an acceptable TLV for JP-4 vapors. Two subsequent studies, a 90-day continuous and a one year 6-hr/day, 5-day/wk, with exposures to 5000 mg/m^3 and 1000 mg/m^3, will be reported in December 1983 and July 1984.

JP-4 causes nonspecific DNA damage in WI-38 cells and possible preimplantation loss in rats during the first four weeks of mating post exposure in the dominant lethal assay. Other mutagenic tests were negative and it was concluded there was no evidence JP-4 would be carcinogenic (Brusick, 1978). A group of Swedish investigators (Knave, 1976, 1978, 1979, 1981) studied engine mechanics who had worked at an aircraft factory for an average of 17 years and had symptoms possibly indicative of polyneuropathy and neurasthenia (nervous exhaustion). These mechanics were exposed to a jet fuel similar to JP-4 at concentrations ranging from 128 to 3226 mg/m^3 while testing engine components, operating test stands, and performing related duties. Exposed workers were significantly different than factory controls in: 1) incidence and prevalence of psychiatric symptoms, 2) psychological tests with emphasis on attention and sensorimotor speed and 3) EEGs.

Carpenter reported acceptable hygiene standards for VM and P naptha and rubber solvent of 2000 mg/m^3 and 1700 mg/m^3, respectively (Carpenter, 1975b, 1975d). The composition of these solvents is similar to that expected from JP-4 vapor exposures.

ACGIH has accepted the recommendation of McDermott and Killiany (1978), of 300 ppm, 900 mg/m^3 for gasoline. This recommendation was based on the ACGIH approach of additivity of effects for the components McDermott identified by gas chromatography/mass spectrometry in gasoline exposures. Many other investigators have also evaluated exposures to gasoline with special emphasis on benzene exposures (Phillips, 1978, Irving, 1979, Runion, 1975). These investigators did not observe significant exposures to personnel during routine handling of bulk quantities of gasoline during either tanker unloading or gas station operations. These investigators also reported the benzene vapor concentration was less than the benzene liquid concentration on a volume percent basis.

NIOSH has recommended a standard of 100 mg/m³ for kerosene based on the assumption of aerosol formation at concentrations above 100 mg/m³ (NIOSH, 1977a). This value of 100 mg/m³ has also been recommended by Carpenter (1976).

In USAF experience, TWA exposures above 700 mg/m³ JP-4 have been indicative of operations which require industrial hygiene controls. Additionally, significant benzene exposures have only been associated with fuel filter replacement. It has been theorized the filters concentrate benzene.

III. CONCLUSIONS

Rationale for a TLV of 700 mg/m³ (200 ppm) and STEL of 1050 mg/m³ (300 ppm) is based on gas chromatograms of JP-4 headspace vapor at 25°C and the ACGIH additivity approach (Table 3). Approximately the same TLV value is obtained using the average benzene and n-hexane vapor concentrations and treating the remaining hydrocarbon vapors as C_7 alkane equivalents. It is recommended that n-hexane be used for instrument calibration to insure intra- and interlaboratory correlations of analytical results (Bishop, 1982). These JP-4 levels are attainable and should provide adequate worker protection based on current toxicologic information. While the extent of skin absorption is unknown, a "skin" notation is recommended because JP-4 is a defatting agent and can cause dermatitis which may lead to increased skin absorption. In the event that an individual is routinely (occupationally) exposed to JP-4 above the "action level" (350 mg/m³), the procedure outlined in Table 4 is suggested minimum requirements for an occupational physical program. This is consistent with the intent of DoD 6055.5-M and should be used within the same context as that document.

TABLE 4

RECOMMENDED MEDICAL SURVEILLANCE PROCEDURES

A. Preplacement Baseline	B. Periodic
1. Medical and Work histories with attention to:	Annually. Same as in A. (except chest x-ray)
a. General physical condition, ability to climb, carry (e.g. rescue buddy), wear protective clothing and equipment	
b. Skin condition	
c. Respiratory system	
d. Personality (e.g., claustrophobia)	
e. Neurological	
2. Physical exam with attention to:	
a. Skin	
b. Peripheral nervous system function	
c. Central nervous system function	
3. Clinical Laboratory Studies:	
a. CBC and differential	
b. Urinalysis with microscopic	
c. 14" x 17" post/ant chest x-ray	
d. Pulmonary function (FVC and FEV_1)	
e. Kidney function (BUN and serum creatinine)	

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